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SDPS Prototyping Plan

White Paper

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RESPONSIBLE ENGINEER

Lynne Case /s/	7/8/94
Lynne Case, SDPS Prototyping Engineer	Date
EOSDIS Core System Project	

SUBMITTED BY

Stephen Fox /s/	7/8/94
Stephen Fox, SDPS Segment Manager	Date
EOSDIS Core System Project	

Hughes Applied Information Systems
Landover, Maryland

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Abbreviations and Acronyms

1. Introduction

1.1 Purpose

This paper describes the short-term prototyping plan for the Science and Data Processing Segment (SDPS). The architecture presented at the System Design Review contains risks that are potentially different from the risks that were identified in the Statement of Work and Hughes' ECS proposal. The purpose of this paper is to identify those risks and describe a prototyping framework that will help to mitigate those risks. The detailed planning of individual prototypes will be documented in separate Prototype and Studies Proposal/Status Forms conforming to the format identified in Appendix B of the Prototyping and Studies Plan (194-317-MG1-001). This paper identifies the prototypes and shows how they fit together with respect to the overall SDPS architecture.

1.2 Organization

This paper is organized as follows:

- Section 1 Introduction- Purpose, organization, and review process for this document.
- Section 2 SDPS Prototyping Needs - This section identifies the risks with the current SDPS architecture and provides the framework in which SDPS prototypes will be developed.
- Section 3 Prototype Summaries - This section summarizes individual prototypes based on the risks described in section 2. These are high level descriptions of the prototypes.
- Section 4 Prototype Management - This section provides a description of how the prototypes will be managed and a high-level schedule and funding summary of the prototypes presented in section 3.

1.3 Review and Approval

This White Paper is an informal document approved at the Office Manager level. It does not require formal Government review or approval; however, it is submitted with the intent that review and comments will be forthcoming. The detailed plans of the prototypes described here will need to go through the approval process described in the Prototyping and Studies Plan. It is not the intention that the prototypes will be approved due to the information contained within this paper.

The ideas expressed in this White Paper are valid for the period 6/94 through 8/94. The concepts presented here are expected to migrate into the formal prototyping plans for the prototypes described in section 3. The data does not migrate into any other contract deliverables.

Questions regarding technical information contained within this Paper should be addressed to the following ECS and/or GSFC contacts:

- ECS Contacts
 - Lynne Case, SDPS Prototyping, (301) 925-0359, lcase@eos.hitc.com
- GSFC Contacts
 - Debbie Blake, SDPS System Engineer, (301) 286-2367, blake@spso.gsfc.nasa.gov

Questions concerning distribution or control of this document should be addressed to:

Data Management Office
The ECS Project Office
Hughes Applied Information Systems
1616A McCormick Dr.
Landover, MD 20785

2. SDPS Prototyping Needs

2.1 Prototyping Framework

Figure 1 shows the SDPS subsystems as presented in the System Design Specification (SDS). In any system it is important to establish the interfaces between subsystems and external systems as early on as possible. In ECS it is even more important to prototype these interfaces due to the fact that the technology being used to provide interoperability between these interfaces is immature. An emphasis on early prototyping for Release A should be to define and implement important subsystem interfaces. The interfaces should be put together in a build thread fashion such that threads of the system can be "executed" to test these interfaces and the mechanisms for interoperation of the interfaces. The interfaces will not only involve the interfaces between subsystems, but they will also include the SDPS to CSMS interfaces. Besides defining and building the interfaces early on, this also provides SDPS with a testbed to resolve COTS integration problems. Both of these activities will help to mitigate the challenging ECS development schedule.

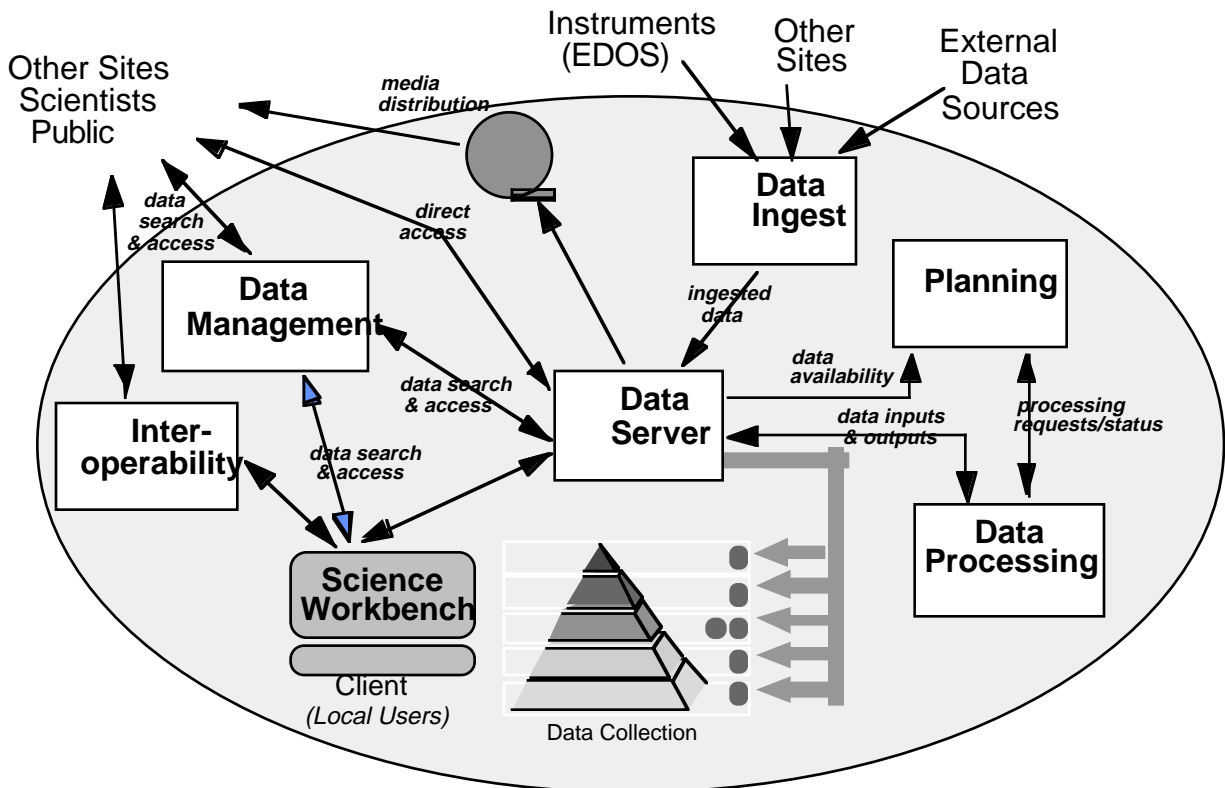


Figure 1. SDPS Subsystem Architecture

Another important benefit of prototyping the interfaces is to provide a benchmark testbed to stress the interfaces with a simulated user load. Rather than primarily modeling the performance of the system, this will provide a framework for measuring the performance of the system and stress testing the infrastructure. The prototype will initially be developed as a subset of the interfaces between subsystems with no underlying functionality. The performance of the interfaces can be measured with simulated data passed around the system. As other prototypes are developed, they can be inserted into this Infrastructure prototype to provide functionality behind the interfaces. Again, the performance of the new components in the prototype can be stressed with a simulated user load. Figure 2 shows the SDPS implementation architecture as documented in the SDS. Note that the actual products used for hardware and software have not been selected. A key part of the stress testing during prototyping will be in the area of COTS hardware and software.

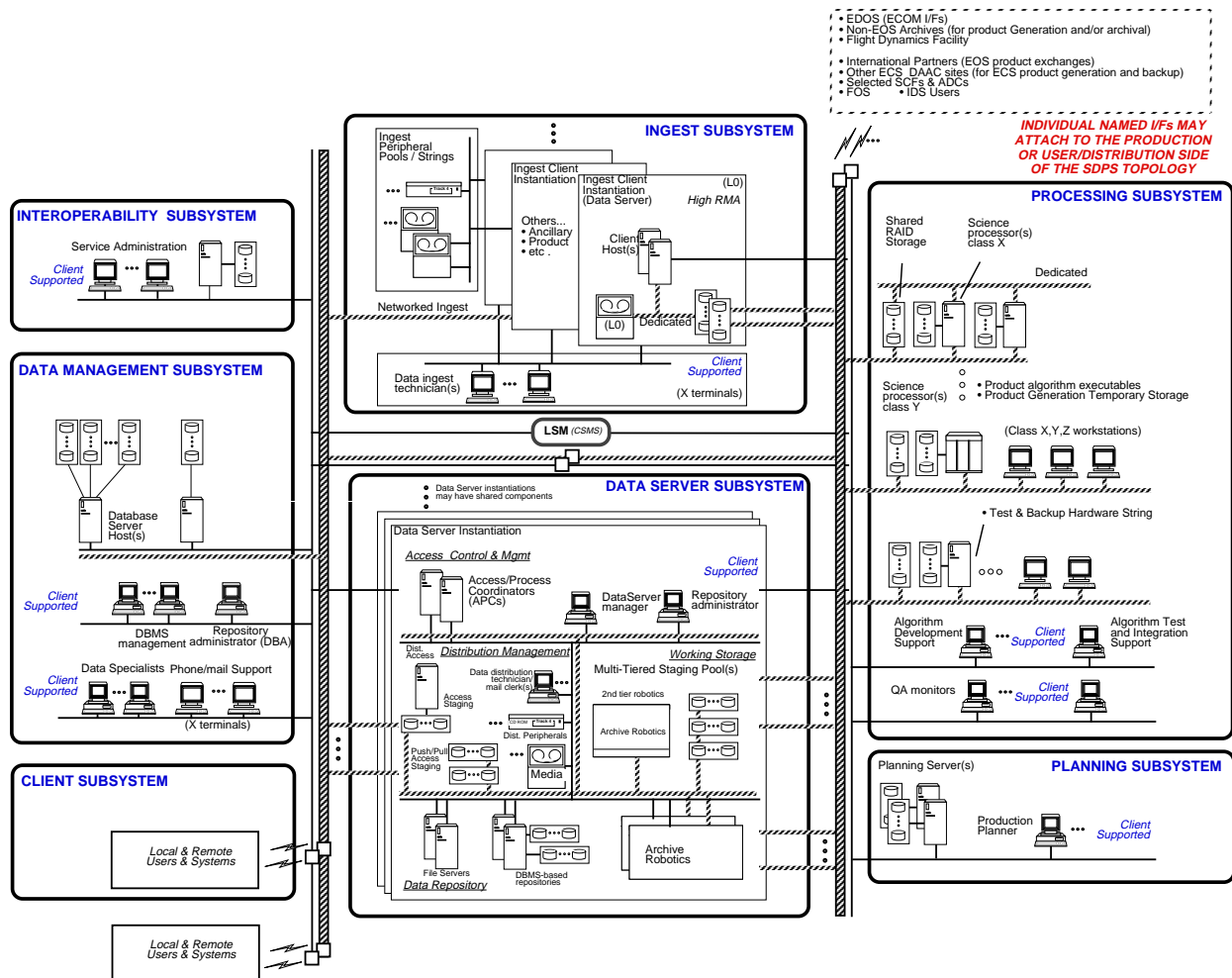


Figure 2. SDPS Implementation Architecture

Figure 3 depicts the prototyping framework. The SDS enumerates the interfaces between subsystems at a high-level. From this specification, SDPS will select important interfaces to prototype. For example, note that many of the client interfaces could be prototyped, but only a few of the Distributed Information Manager (DIM) and Local Information Manager (LIM) interfaces would be. Also notice that as the Advertising Service prototype and the Multi-FSMS prototype become available, they will be plugged into the framework in the appropriate places. In this way, a subset of the system can be put together from the individual prototypes which focus on small components of the system rather than large subsystems. The Advertising Service and Multi-FSMS prototypes in this figure are examples. Many more of the other prototypes could be used to plug into the framework as well. Another advantage to this approach is that the prototypes can be packaged and delivered as part of the Evaluation Packages.

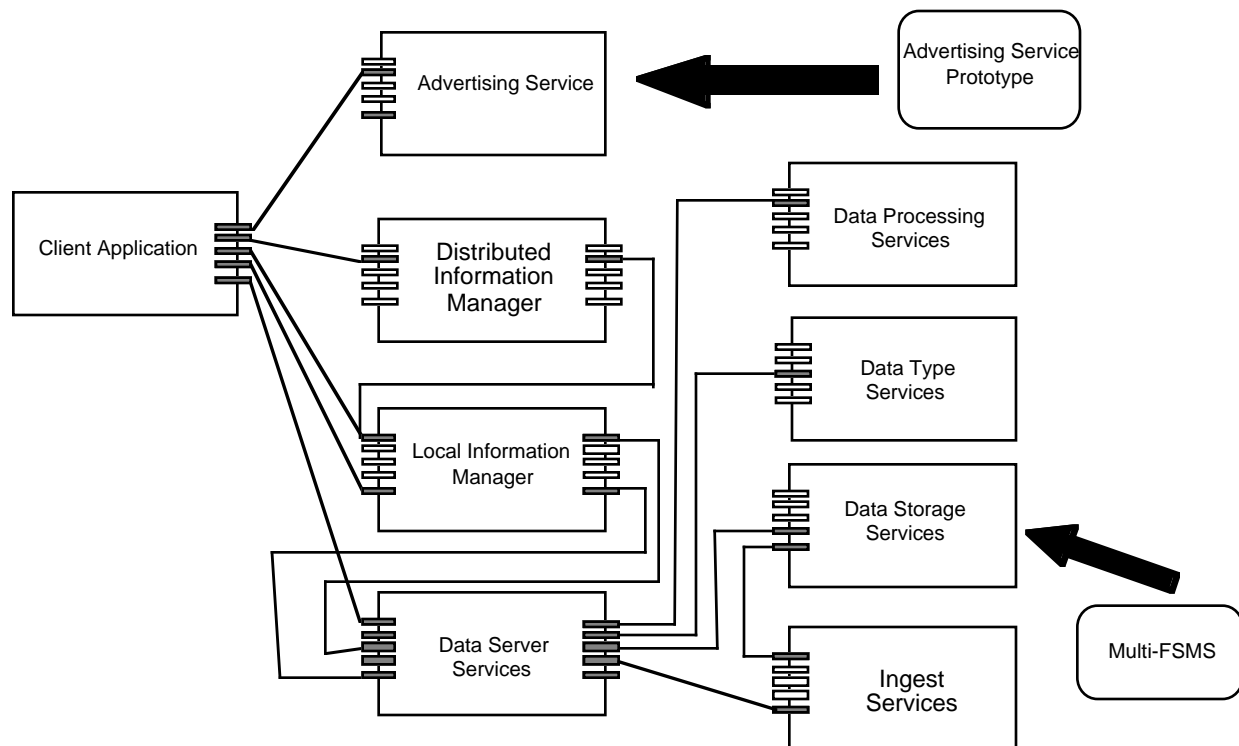


Figure 3. Prototype Framework Example

2.2 Prototyping Motivations

There are several incentives for performing prototypes. Descriptions of the major reasons follow.

- Requirements uncertainty - Prototypes can be used to determine the correctness and completeness of requirements.

- Design correctness - Prototypes can be used to determine if a particular design concept is correct. These prototypes are usually developed for fundamental design concepts, that is design features that are essential to the entire system or subsystem. This is the reason for proposing the Infrastructure Prototype discussed earlier.
- Design completeness - Prototypes can be used to determine if something is missing in a design. An example of this would be the Trader service. It needs to be understood whether the CORBA compliant Trader service is sufficient to provide the features necessary for the advertising service.
- Mitigating Risk - This is similar to design correctness. There are usually major risk areas in the design. Prototypes are developed to ensure that as much is learned about the risk as possible before going into full scale development.
- Technology - Prototypes can be developed to determine the applicability of specific technology areas to a problem. Many times these can be paper studies or ad-hoc evaluations of products. Other times it is necessary to actually integrate the product into a working prototype to establish how it performs within the correct framework.

Table 1 outlines the ECS program risks that affect SDPS. These risks come directly from the ECS Program Risk List that is being compiled and tracked by SI&P. Only the User Interaction, Architecture, and Technology risk areas are presented. Prototyping with new technologies in general should contribute to mitigating the risks involved with Evolution, System Operations, and Programmatic. There will not be a one-to-one mapping of prototypes to risks. Sometimes multiple risks will be addressed in a single prototype and other times a prototype may address multiple risks. The description of each prototype will be presented in section 3. The intent of the prototyping effort will be to develop independent prototypes that will fit into the prototyping framework. Section 2.2 will discuss the guidelines for prototypes that will allow us to do this.

Table 1. ECS Risks Related to SDPS (1 of 3)

#	Name	Problem Description	Prototype Focus
U-2	Interoperability of Earth Science Data Models	In most cases, the data models at the data providers will be at least slightly different. A mechanism must exist to map or interuse vocabulary and data dictionaries between sites. The ability to do this is a key area of the SDPS architecture.	Test the core metadata and vocabulary defined by the information and data modeling teams. Prototype the use of multiple vocabularies and data dictionaries in a prototype.
U-4	Processing and Storage for Standard Products	Growth in science algorithms may exceed available resources of processing and storage	Prototype science algorithm processing on a variety of hardware and software configurations.
A-2	Resource Management with Diverse Users	Effect of diversity of users and data providers on overall system performance. There exist technical questions about the feasibility of effectively allocating resources between extremely high-end data interactive users and the larger numbers of lower end "browse and order" users.	SDPS prototypes and studies should focus on the following: <ul style="list-style-type: none"> - Automated production planning and scheduling - Viability of object caching.
A-5	User Interaction with Archived Data	To support a high degree of interactivity with the large volume of EOS data, advances may be needed in DBMSs, networking, browsing, visualization tools, storage access speeds, and video teleconferencing performance and functionality.	SDPS prototyping and studies should focus on stress testing a "system" made up of important components. This is the focus of the Infrastructure Framework prototype. Individual pieces will be benchmarked and stress tested such as in the Data Type Services and Storage Systems Stress Test.
T-1	Immaturity of CORBA	CORBA has been identified as the best candidate for the interoperability and interconnection standards. The COTS products to support the standard as well as the standard itself are very immature.	Use COTS ORB and trader (if available) and test likely access patterns. (This is CSMSs role and is documented here because of its relationship to the SDPS architecture.)
T-2	Earth Science Data Language	The query language(s) used when accessing services within the SDPS architecture has not been defined. The language must be extensible to handle new objects as well as new data types. The transport mechanism also has not been defined. Possibilities that have been discussed are Z39.50, CLI, and RDA.	A study should focus on the following issues: <ul style="list-style-type: none"> - What is the query language? - Are there more than one? - Transport mechanism?

Table 1. ECS Risks Related to SDPS (2 of 3)

#	Name	Problem Description	Prototype Focus
T-3	Storage Management Interoperability Standards	Standards need to be developed to enable interoperability between different vendor's storage management products. The current lack of these standards makes it impossible to mix products from different vendors to achieve the best performance at the lowest cost, and makes it difficult to insert new products as they emerge.	Prototype systems with multiple storage management systems and file storage management systems.
T-4	COTS Hierarchical Storage Management	Commercial software products (e.g. storage management systems and distributed file systems) need better reliability and performance. Without such improvement, these products are likely to be key limiting factors in the overall system performance.	A study and prototypes should focus on the following areas: <ul style="list-style-type: none"> - Multi-FSMS integration - File Storage Manager Systems Evaluation
T-5	Cost Effective Storage Technology	The future of storage technology is uncertain and evolving slowly. High density storage media with greater reliability and lower cost are desired, as well as associated devices with better performance characteristics. The significant role of data storage in the system means that improvements in this area would have a significant impact on the cost and performance of the overall system.	Studies and prototypes should be focused on the following areas: <ul style="list-style-type: none"> - Storage Technology Market Assessment - Network Attached Storage - Data Compression - Storage Tech. Insertion Plan
T-7	DBMS	Relational DBMSs currently do not meet all of the ECS requirements, but Object-Oriented DBMS or Object-Relational DBMS, while offering considerable potential are less mature and untried at the scale of ECS. An approach of utilizing current technology (RDBMS) and transitioning to OODBMS is not an option because: (1) the models are different, and (2) the costs of changing are significant. Wrappers are also unlikely to be successful for ECS because of the performance issue.	Perform evaluation and prototype pieces of the architecture that need complex data structures (such as spatial indexes). The DBMSs will be stress tested with large amounts of data to determine the stability of the products as well as their performance.

Table 1. ECS Risks Related to SDPS (3 of 3)

#	Name	Problem Description	Prototype Focus
T-8	Scalability & Maintainability of Archives	The projected size of the ECS archives raises general questions about the scalability of current systems and the maintainability of large, long-lived archives. For example, while smaller systems may handle migration of data to new storage products by copying files, this is probably not a viable option for ECS given the projected size of the archives and the current performance of data copy operations.	The Network Attached Storage prototype will help to reduce the need to have multiple copies of the same large files within the same provider site. This will help mitigate the scalability factor. For maintainability the robotics surveys previously performed provide SDPS with the knowledge to pursue stable products. The Multi-FSMS Integration prototype allows the use of multiple archive types therefore allowing for differently sized data providers.
T-9	DCE Immaturity for Release A	Release A may be affected by the immaturity of DCE with respect to robustness, performance, and the breadth of supporting products. Performance may be affected as the usage is scaled up, E.g. over ATM. The breadth of supporting products for using DCE may limit implementation choices for Release A.	(This risk will be handled by CSMS, but SDPS prototypes must be involved to provide realistic user and data loads on DCE.)

Table 2 shows additional areas requiring prototypes. These are issues are documented in the SDS as well as in the SDPS Implementation Architecture white paper, therefore the descriptions here are very concise. For more detailed descriptions refer to the SDS. ***Only the design issues that have not been addressed at SDR are included. Some of them will not be handled in prototypes and thus are not listed here. Also, some of the design issues in the SDS are also directly related to the ECS risks. These design issues are not repeated here since they are in Table 1 as part of the ECS risks.***

Table 2. SDPS Design Issues

#	Name	Problem Description	Prototype Focus
DI-1	High Speed I/O Solutions	Technology tradeoffs are needed to mitigate the large I/O requirements between ingest, archival, and processing.	PDR/CDR trade for SDPS Network Architecture and Network Attached Storage.
DI-2	Data Volume Reduction	Data volumes are a significant driver in the cost and performance of the physical design.	Evaluate data compression as it affects SDPS as a whole.
DI-3	File Storage Management Systems	Supporting diverse ECS data access requirements with FSMS.	Continue assessment of FSMS as well as studying the physical allocation of data, hardware, and software.
DI-4	Data Dictionary / Vocabulary Complexity	Large degree of complexity in the design of data dictionaries.	Through technology assessment and other uses of DBMS technology, evaluate ways of supporting with COTS.
DI-5	Client Platform Compatibility	Diversity to the look and feel of the native platform user interfaces needs to be addressed	Focus on user interface standards to provide common look and feel across platforms.
DI-6	Processing Hardware Selection	Processing Hardware is significant cost driver.	Determine how to distribute processing across pooled or dedicated resources.
DI-7	Distributed and Parallel Computing for Science Algorithms	Distributed and parallel processing of algorithms will help reduce the cost and increase efficiency of hardware for processing.	Work with real science algorithms to benchmark different distributed and parallel processing configurations. Also use these algorithms to prototype the software that is necessary to run the algorithms and evaluate algorithm portability issues using the PGS toolkit.
DI-8	Scheduling Design	Need to know how COTS scheduling and planning systems relate to SDPSs requirements in these areas.	Assess current COTS technology in scheduling and planning. Use selected packages to prototype aspects such as centralized vs. distributed planning.

2.3 Prototyping Guidelines

The approach that is to be taken with the SDPS prototypes is to allow independent prototypes to be developed as long as some guidance is provided along the way. The guidelines are necessary to ensure that the prototypes fit together for the following reasons:

- If prototypes can be put together, we can demonstrate larger pieces of functionality. For example, creating an advertising service prototype will be useful to uncover issues with the Trader, but connecting it with a client will allow us to learn more about how the client will use it.

- Without integrating the pieces together to make larger pieces, we will not flush out some design issues. For example, if we do not integrate the data processing prototypes with the data server and data ingest prototypes, we will not be able to flush out the transaction management issues.

The guidelines should apply to all prototypes that are destined to provide prototype components to be integrated into the framework, including those developed by sources external to the ECS contractor. The guidelines can be deviated from with only two types of prototypes. The first type is a proof-of-concept prototype in which it is not possible to fit into the framework. An example of this type might be a prototype using an interface different than the ones specified in the SDS to trade-off alternatives in design. The second type of prototype that may not have to meet the guidelines is a COTS product evaluation where no custom code is being developed. The COTS product is being evaluated, but not integrated as a component in the architecture. An example of this type of prototype might be a comparison of robotics technology where several alternatives are being benchmarked, but the Data Storage Services are not actually being developed around the products.

The following guidelines must be adhered to:

- Service Interfaces - The current services interfaces must be adhered to as described by the design documents / white papers available at the start of the prototype. This includes inter-site service interfaces as well as inter-subsystem service interfaces. If external organizations are involved in the prototype, it is the responsibility of the Prototype Manager (as defined in the Prototyping and Studies Plan) to monitor the progress of the prototype and inform the developers of major changes to the service interfaces.
- CSMS Interfaces - The CSMS interfaces should be used as described by CSMS design documents / white papers. The purpose of this is to prohibit the use of client/server communications that will not be used on the program and to ensure that the prototype will work under the environment that will be provided by CSMS. For example, there is no reason for a prototype to be built over DECNet if this is a protocol that will not be supported by CSMS.
- Data Format(s) - Any data formats that are used should conform to the standards set for the ECS project. For example, the current data distribution standard is HDF. This format should be used in any prototypes that model distribution requests, unless the purpose of the prototype is to provide data conversions to other formats.
- Programming Language(s) - The programming languages that will be used for new code are C and C++. There are two cases where a prototype may deviate from this guideline: (1) when the purpose of the prototype cannot be accomplished with C or C++ and (2) when existing code cannot interface with C or C++. The use of C is allowed due to the fact that some COTS products and heritage code still cannot be interfaced with C++. An example of this would be the DCE toolkit. The IDL compiler in DCE currently generates C code not C++, therefore C must be allowed in prototypes. C++ should be used whenever possible.

It is the responsibility of the organization performing the prototype to adhere to the guidelines specified above. The Prototype Manager is responsible for ensuring that the performing organization has the current design information necessary for compliance to the guidelines. The Prototype Manager must also monitor the status of the prototype to ensure that the prototype continues to comply to the guidelines throughout development.

2.4 External vs. Internal Prototypes

The Prototyping and Studies Plan (194-317-MG1-001) outlines three classes of prototypes. Two of the classes are typically prototypes that are built by the ECS contractor. The third class is typically produced by sources external to the ECS contractor. The definitions of the three classes are as follows:

- **Advanced** - Advanced prototypes and studies are used to evaluate the feasibility of a new concept with the intent on investigating potential new requirements or alternative implementations. This is the class that is typically performed in partnership with external organizations.
- **Engineering** - Engineering prototypes and studies are used to test the feasibility of a design or implementation concept. They are usually targeted at a specific release and design problem. This is why they are not good candidates for partnerships. ECS must have tight control over the schedule of these prototypes to meet design phases. These prototypes could be used to bring in advanced prototypes and tie them together with other ECS prototypes.
- **Technology Analysis** - Technology Analysis prototypes and studies are used to evaluate COTS products, shareware, public domain, other prototypes, and new technologies. Results of these prototypes usually impact a specific design decision of a release. Again, these prototypes are usually performed by the ECS contractors in order to meet design review schedules and deliverables.

Each prototype described in section 3 will be designated as internal, external, or joint. Joint prototypes are ones that are performed partly by ECS contractors and partly by external organizations. In all cases, the ECS contractor and the ESDIS project will be monitoring the status and results of each prototype. Section 4 describes how prototypes are managed in detail. The Prototyping and Studies plan describes in detail how the prototypes will be approved and initiated.

2.5 Prototype Results Evaluation

The main objective in prototypes is usually to help mitigate some risk or solve a design problem through study and evaluation of alternatives. The prototype can not always be used directly in the system, because of the nature of prototyping. SDPS prototypes will be evaluated by the appropriate SDPS development teams to determine: (1) what features and code of the prototype will be retained in the SDPS implementation, (2) what features and code must be enhanced in the SDPS implementation, and (3) what features and code are not appropriate (and dropped) in the SDPS implementation. As implied in the above list, the code must be reviewable by SDPS development teams to determine what can be directly infused into the multi-track development process.

The following evaluation criteria should be used when evaluating the results of prototypes or studies. This list can be traced to the ECS Prototyping and Studies Plan.

- Success Criteria: Did the results of the prototype or study satisfy the objectives set out in the prototype proposal?
- Cost Containment: Is the proposed solution cost-effective over the projected life cycle?
- Evolveability: Is the proposed solution amenable to future changes in the configuration or design of the ECS or of technology? Is the solution subject to scaling in the event that performance requirements are changed?
- Manageability: Does the proposed solution support the ECS evolutionary development cycle and the multi-track development approach?
- Architecture Conformance: Does the implementation of the prototype result fit into the existing ECS architecture?
- Performance to Requirements: Does the proposed solution maintain or ease adherence to requirements?
- Site autonomy: Does the proposed solution imply avoidable dependencies between data providers?
- Conformance to Guidelines: Does the proposed solution conform to the guidelines established in this plan?

3. Prototype Summaries

3.1 Prototype Traceability

Table 3 shows the traceability of risks to the prototypes that will be discussed in this section. There are some risks that will not be prototyped but will be resolved primarily through design studies and trades. The Infrastructure Framework prototype is the unifying component to the prototypes. It will allow for all the prototypes to be integrated into a partial system that can be exercised to test user loads.

Table 3. ECS Program Risks to New Prototypes Traceability

Prototype Name	U-2	U-4	A-2	A-5	T-1	T-2	T-3	T-4	T-5	T-7	T-8	T-9
Infrastructure Framework				X	X							X
EOSDIS Prototype					X							X
Advertising Service					X					X		
Data Type Services				X						X		
Earth Science Languages and Protocols						X						
Schema Maintenance Prototype	X											
Local Information Manager	X									X		
Distributed/Parallel Computing of Science Algorithms		X										
Network Attached Storage							X		X		X	
Multi-FSMS Integration							X	X			X	
SDPS Planning and Scheduling			X									
Data Compression									X			
Storage Systems Stress Tests & Benchmarks		X		X								
Physical Data Format Standards Study												
Data Processing		X										
Data Dictionaries / Vocabularies	X									X		
Data Migration												

Table 4 shows the relationship of SDPS design issues to SDPS prototypes. The design issues come from Table 2. The figure shows the prototypes that will be used to satisfy the design issues. In some cases, the prototypes are duplicated from Table 3. These are in fact the same prototype, but are shown here for completeness.

Table 4. SDPS Design Issues to New Prototypes Traceability

Prototype Name	DI-1	DI-2	DI-3	DI-4	DI-5	DI-6	DI-7	DI-8
Infrastructure Framework								
EOSDIS Prototype					X			
Advertising Service								
Data Type Services								
Earth Science Languages and Protocols								
Schema Maintenance Prototype								
Local Information Manager								
Distributed/Parallel Computing of Science Algorithms						X	X	
Network Attached Storage	X					X		
Multi-FSMS Integration			X					
SDPS Planning and Scheduling								X
Data Compression		X						
Storage Systems Stress Tests & Benchmarks								
Physical Data Format Standards Study			X					
Data Processing						X	X	
Data Dictionaries / Vocabularies				X				
Data Migration								

The following sections provide a summary of the prototypes shown in Table 3 & 4. The actual prototyping plans will be provided as separate documents so the details of each prototype can evolve without affecting this white paper.

3.2 Infrastructure Framework

3.2.1 Description

As discussed earlier in this paper, the Infrastructure Framework Prototype is a prototype to define and test the interfaces between subsystems. This prototype will require support from all the prototyping teams within SDPS as well as support from the CSMS prototyping team. The following general steps should be taken to complete this prototype:

- Define the service interfaces that will be included in this prototype. Not all service interfaces will be defined but the interfaces that are risky or ill-defined should be included.
- Prototype the interfaces. Each prototyping team should developed the interfaces required for their subsystems.
- Integrate the interfaces. The teams should work together to make sure the interfaces work as expected.
- Test the interfaces. A simulated user load should be placed on the prototype to determine where the technology / performance breaks down.

This will be an on-going prototype. As the other prototypes get developed, the actual implementation will get inserted in place of the stubs that will be used initially. In this way, the implementation of the prototype will be stress tested under the simulated user load. Not all prototypes will be integrated, but enough should be done to build major portions of the system.

3.2.2 ECS Benefit

The benefits of this prototype for ECS are:

- Provides a testbed for simulating user interactions with the system whether the users are people or programs, as well as providing a mechanism for integrating future prototypes.
- Helps define the interfaces between subsystems.
- Creates working relationships between subsystems on segments.

3.2.3 Community Benefit

The benefits of this to the general community are:

- Provides an early definition of what the service interfaces will be. This gives an early view of the APIs users will be developing with.

3.3 EOSDIS Prototype

3.3.1 Description

In preparation for the ECS System Design Review (SDR), Hughes Applied Information Systems (HAIS) has been designing a system architecture capable of responding to a broad set of needs in the user community. These needs include the science and technology drivers outlined in "Science-based System Architecture Drivers for the ECS Project". The result of this analysis has been the development of a new, open distributed system architecture for ECS that is predicated on, among other things:

- Heterogeneity and Autonomy of Service Providers in an extensible Provider Network
- Support for Data Search and "Access" as opposed to "Approval and Order" • An extensible Client Subsystem based on emerging desktop and document framework technology, and aimed at integrating existing and emerging investigator analysis tools, including collaboration environments
- An interoperability infrastructure that facilitates the migration of services among system components as resource needs change

One of the key features of the new architecture is its ability to support an "extended provider network". This is the concept of a "federation" of data providers beyond the Distributed Active Archive Centers (DAACs). These providers will augment DAAC product holdings by providing their own data products to segments of the community. For example, Science Computing Facilities will develop relevant correlative and alternate source data holdings used in their research -- products that might be useful to the wider scientific community. The Landsat

Pathfinder IMS at the University of New Hampshire currently includes alternate high resolution imagery sources that could be made available to the community. The ability of facilities like the UNH SCF to become a provider of data to the community is one of the more powerful features of the ECS architecture.

This prototype investigates key issues in providing the functionality described above to the EOSDIS community. It builds on a collaborative effort between OSU and UNH begun as part of the NIIT EarthDS application, exploring the roles of SCFs as both data consumers and data providers through:

- SCF-to-DAAC interactions (data access)
- SCF-to-SCF interactions (collaboration, extended provider support)

The first of these aspects is one of the fundamental Science Drivers expressed in the new architecture "mandate", i.e. the "publishing and access" paradigm. The second is an area outside of the ECS project scope, but clearly an area that must be enabled by ECS if the project is to succeed in its mission to supply scientists with the tools and data they need to perform their research.

3.3.2 ECS Benefit

The benefits of this prototype for ECS are:

- Prototype code using desktop standards for future computing environments.
- Helps define the interfaces between client and the advertising service or trader.
- Creates working relationships with current data providers.

3.3.3 Community Benefit

The benefits of this to the general community are:

- Allows the data providers to get involved with the ECS prototyping process.
- Allows the data providers insight into the interactions that they will have with the ECS system.
- Explore operations concepts and technologies to support EOSDIS.

3.4 Advertising Service

3.4.1 Description

There are currently two alternatives for implementing the Advertising Service Application. The first is to provide an interface to a COTS / CSMS developed trader. The second alternative is to build the advertising service on top of a DBMS that stores the service offers in addition to information about data repositories. During this prototype both solutions will be investigated. The main tasks of this prototype will be:

- Determine the potential of using the ODP based trader by working with CSMS to analyze the required capabilities of the advertising service against the functionality of the trader. SDPS will also work with CSMS to determine if COTS traders will be available for each of the Releases and EPs.
- Given the answers to the above questions, prototype the advertising service either as an interface to a CSMS provided trader or as an interface to a DBMS repository of service offers. This interface should include both the user interface to the advertising service as well as the API interface to the advertising service.

3.4.2 ECS Benefit

The benefits of this prototype for ECS are:

- Prototype code for the Advertising Service Application.
- Helps to flush out the design of some of the other client subsystem components.
- Helps to define the data required for the data and service offers managed and used by the advertising service.

3.4.3 Community Benefit

The benefits of this to the general community are:

- Provides a definition of the data formats required by the advertising service.

3.5 Data Type Services

3.5.1 Description

One of the key risk areas on the ECS Program Risk List is the DBMS technology as applied to the management of Earth Science Data Types. The data stored in the data server context is the most complex and abundant in ECS. The efficient management and searching of this data is essential to allow users to retrieve information in a timely manner. The focus of this prototype will be to evaluate DBMS technology as they apply to the data type services. A technology assessment of DBMSs is on-going at this time, including relational DBMSs, object-oriented DBMSs, and object-relational DBMSs. The output of the technology assessment activity should

be to document where the current DBMS technology is and where it is going in the future. Based on this assessment, potential DBMS products will be selected to prototype the data type services and the local information manager (see the Local Information Manager prototype).

Some of the key requirements that the DBMSs will be evaluated on are:

- Support for complex data types and operations on those data types.
- Support for data structures that will allow us to efficiently store and search spatial data held in a variety of reference frames. In some cases this is provided through data types provided by the DBMS and in other cases ECS will have to provide this by defining complex data types with operations through the requirement specified above.
- Support for large objects and large numbers of objects.

The entire list of key requirements is being documented in a white paper (DBMS Evaluations MA9401V1). This paper will be updated to include the results of the evaluation as it progresses.

3.5.2 ECS Benefit

The benefits of this prototype for ECS are:

- Experience will be gained on a variety of DBMSs and DBMS technologies.
- Prototype code will be produced for spatial searching, data loading, etc.

3.5.3 Community Benefit

The benefits of this to the general community are:

- Evaluation of the current and future state of DBMS can be provided to other system builders.

3.6 Earth Science Languages and Protocols

3.6.1 Description

Currently, the Earth Science data definition and query language(s) have not been selected. There are many alternatives and standards that can be investigated such as SQL3, OQL, etc. Not only have these languages not been fully defined, but the mechanism for transferring the requests from clients to data management and data servers has also not been defined. The transfer protocol may be dependent on the language being used for a particular purpose and component. As a result, the decisions for the languages and protocols are tied together and have to be addressed somewhat in parallel. The main goal of this prototype should be:

- Define the data definition, query, and access languages and the transfer protocols used for each. It is possible that there will be one language that handles all types of requests such as SQL3, but the option is left open to have more than one. The data server hides any internal protocols from the users accessing ECS. It is also likely that there will be different languages for Earth Science Data Types and document data types. The protocols for these may also be different.

- Prototype interaction between a client and servers using the languages and transfer protocols on top of CSMS provided services.

3.6.2 ECS Benefit

The benefits of this prototype for ECS are:

- Establish the language that will be used to drive the interface to subsystems such as the DIM, LIM, and data server.
- Prototype code for building searches, data definitions, and data requests and transferring them to other subsystems.

3.6.3 Community Benefit

The benefits of this to the general community are:

- Definition of the languages and protocol that should be used to communicate to ECS services.

3.7 Schema Maintenance

3.7.1 Description

The methodology for integrating or federating schemas has not been defined as part of the architecture. It has been assumed that human interaction is involved when integrating or federating schemas into the LIMs and DIMs. There is some research on-going in this area that should be evaluated for possibly automating some of the work. In addition to the act of integrating and federating the schemas, there must be mechanisms in place for generating the schemas. The focus of this prototype will be to prototype the schema generation application for the data server and determine how the schema gets integrated at the LIM based on the research of schema integration techniques.

3.7.2 ECS Benefit

The benefits of this prototype for ECS are:

- Provide prototype code for schema generation and integration.

3.7.3 Community Benefit

The benefits of this to the general community are:

- Provide a definition of how the administrators of the schemas will interact with the system to generate and integrate schemas.

3.8 Local Information Manager

3.8.1 Description

The LIM provides access to data located within multiple data servers. There are two general approaches to the LIM design:

- The LIM will be very similar to the DIM and there will be much reuse in the code developed for each.
- The LIM functionality will be folded into the data server and the LIM will not exist in ECS as a separate component.

A prototype of the LIM functionality will help to flush which of the above assumptions will prevail in the architecture. The prototype will concentrate on providing the functionality of the LIM Application rather than the schema maintenance or integration.

3.8.2 ECS Benefit

The benefits of this prototype for ECS are:

- Help determine the best approach to the LIM design.

3.8.3 Community Benefit

The benefits of this to the general community are:

- Not applicable.

3.9 Distributed/Parallel Computing of Science Algorithms

3.9.1 Description

One of the biggest risks in ECS is the large processing requirement of science software. A possible solution to meet this requirement is a multi-processor environment. This prototype will investigate possible portability problems or inefficiencies in science software run in this environment which is different than the environment in which they were originally developed. The prototype will look at alternative ways of porting science software to and between multi-processor environments. Multi-processor environments include distributed cooperative computing with homogeneous or heterogeneous clustered workstations, parallel programming on multiprocessor workstations, and parallel programming on massively parallel systems.

One algorithm that will be used for the prototype is the Pathfinder AVHRR GAC algorithm. This is a good candidate since it is a mature algorithm that has been in production for some time. Another advantage is that it is seen as an early prototype of the MODIS processing science software. The data that is generated can be used in other prototypes in the data server and data management subsystems. Other representative science software that will be considered for porting will come from other Pathfinder projects and early ECS instrument team science software.

In support of this prototype a computing testbed is being established to explore these multi-processing options. In addition, this prototyping effort plans to take advantage of computing resources at various sites which can make available specific processing architectures (e.g., HPCC).

3.9.2 ECS Benefit

The benefits of this prototype for ECS are:

- Develop additional potential processing costs information based on the observed performance of typical science software on various multi-processor environments
- Test algorithm integration and test environment and procedures using the PGS toolkit.
- Test processing architecture as it is developed.
- Provide test data and metadata for the archive and data management services.

3.9.3 Community Benefit

The benefits of this to the general community are:

- Additional information to enhance understanding of alternative architectures and their advantages and disadvantages
- Potential to provide science software development guidelines to the community for multi-processing optimization and/or portability

3.10 Network Attached Storage

3.10.1 Description

This prototype will investigate ways to implement network attached storage. Attaching the storage to the network will reduce CPU loads associated with I/O operations between subsystems such as Ingest, Processing, and Archive Services. These subsystems may benefit by being able to read and write from the same RAID device attached to the network, eliminating the need to transport the data from one host to another.

3.10.2 ECS Benefit

The benefits of this prototype for ECS are:

- Investigate improving system performance by off-loading data flow from a central host computer
- Investigate potential for reducing the cost stemming by using smaller distributed computers and storage resource sharing
- Attempt to maximize the modularity and evolvability of design

3.10.3 Community Benefit

The benefits of this to the general community are:

- If the prototype is successful, ECS network attached storage architecture can be used in a variety of medium-sized to large storage systems

3.11 Multi-FSMS Integration

3.11.1 Description

Alternatives for implementing access to heterogeneous file storage management systems (FSMS) has been studied in relationship to the envelopment of V0 archives. Representative candidates will be prototyped to assess the validity of the designs.

The prototype is focusing on interoperability and intercommunication between heterogeneous systems. Instead of concentrating on specific storage methods and capabilities, though these factors will be discussed and recorded, the investigation will be of intercommunications capabilities available from each product/host. (e.g. NFS, RPCs, AFS, FTP, RCP, etc.) Emphasis will be on developing a unified general interface layer that will present a single communications capability to external requests. The goal is to encapsulate individual heterogeneous systems in such a way that they appear to be one large, efficient system.

3.11.2 ECS Benefit

The benefits of this prototype for ECS are:

- Proof of the ability to integrate heterogeneous FSMS within an archive seamlessly and efficiently
- If the prototype is successful, ECS can benefit from using several FSMS, each with its unique benefits for the overall system.

3.11.3 Community Benefit

The benefits of this to the general community are:

- If the prototype is successful, integrated heterogeneous FSMS can be used in a variety of medium-sized to large storage systems

3.12 SDPS Planning and Scheduling

3.12.1 Description

There is a technology assessment effort currently under way to investigate COTS planning and scheduling packages. One of the candidates is Delphi, which is currently being used in the FOS planning and scheduling prototypes. This prototype will participate in the assessment of these COTS packages and use selected packages in a prototype of the Planning and Scheduling Application.

3.12.2 ECS Benefit

The benefits of this prototype for ECS are:

- Determine state of the art COTS planning and scheduling systems.
- Prototype code targeted directly at the Planning and Scheduling Application in the SDPS architecture.

3.12.3 Community Benefit

The benefits of this to the general community are:

- Early prototype can be used at SCF for algorithm testing and within the EDF as part of the Infrastructure Prototype.

3.13 Data Compression

3.13.1 Description

A design trade scheduled for PDR is focused on data compression. Compression can reduce storage costs as well as network bandwidth required. It can increase the cost of client workstations for decompressing the data. Part of the PDR trade will be to determine the impact of compression on ECS as a whole. A second part of the trade will be to determine the compression techniques most applicable to ECS data. The results of this trade will be the basis for a prototype that will incorporate the results. The prototype will test the affect of compression on the architecture using the techniques determined to be applicable to ECS data types.

3.13.2 ECS Benefit

The benefits of this prototype for ECS are:

- Prototype code using COTS compression software that can be integrated into SDPS components in the Ingest Client, the Client Subsystem, and the Data Distribution Service.
- Provide realistic performance information for use in system design and configuration.

3.13.3 Community Benefit

The benefits of this to the general community are:

- Definition of guidelines for data product definition and structuring to maximize compression potential.

3.14 Storage System Stress Tests and Benchmarks

3.14.1 Description

This prototype will be used to test alternative archive architectures for the Release A configuration. An assumption is made that the candidate configurations for Release A have been

selected. This prototype will test the performance and reliability of these candidate solutions. The purpose of the prototype is to verify or invalidate the candidates identified through PDR trade studies.

3.14.2 ECS Benefit

The benefits of this prototype for ECS are:

- Validates the PDR selections for archive configurations.

3.14.3 Community Benefit

The benefits of this to the general community are:

- Provide performance figures for candidate architectures to system builders.

3.15 Physical Data Format Standards Study

3.15.1 Description

The organization of the data within the archive directly affects the ingest and retrieval performance of the archive. This study involves using the User/Data Model results to identify candidate methods of organizing ECS data from an earth science point of view in order to minimize response times and reduce media handling. The study will recommend one or more candidate data architectures (within one or more Data Servers) for incorporation into a prototype. Separate recommendations will be made for general data versus browse data.

3.15.2 ECS Benefit

The benefits of this prototype for ECS are:

- Define the strategy for the physical location of data within the Data Server.
- Provide this information for incorporation into another prototype to test the conclusions.

3.15.3 Community Benefit

The benefits of this to the general community are:

- Not applicable.

3.16 Data Processing

3.16.1 Description

The overall aim is in generating a demonstration system for the processing services, and through this, providing an environment for investigation of data processing issues. The prototype covers four of the service classes identified in the architecture: Process Management, Process Queuing, Process Execution, Process Resource Management and the appropriate user interface components to interact with the services. The prototype identifies and utilizes freeware and

custom software that may be used to generate a rapid solution to the processing system, and performs an iteration using these components to prototype the full data processing architecture.

3.16.2 ECS Benefit

The benefits of this prototype for ECS are:

- Demonstrate feasibility and investigate implementation issues for processing subsystem architecture.
- Provide mechanisms for interfacing with PGS toolkit
- Investigation of emerging CSMS interfaces.
- Capability to interface with AI&T and Planning/Scheduling Prototypes for complete data production prototype at completion of this prototype.

3.16.3 Community Benefit

The benefits of this to the general community are:

- Support possibility of early AI&T and provide data processing testbed.
- Provide support / direction to SCFs for algorithm development and integration.

3.17 Data Dictionaries and Vocabularies

3.17.1 Description

The ECS Program risk, 'Interoperability of Earth Science data models (U-2)', states that common data models must be established to enable interoperability of multiple sites. In some senses, ECS will provide this by defining a set of core metadata attributes that all ECS products will generate during processing. This does not solve the problem however. Not only are the data diverse in ECS and GCDIS, but the users are diverse. Each user will have a different interpretation of an attribute or keyword. The data dictionary is vital in allowing users to determine the definition of terms. The system must also transparently map vocabularies between users and data providers.

The Data Dictionaries and Vocabularies prototype will focus on providing the data dictionary services using DBMS technology. The DBMS technology assessment effort must take into account the needs of the data dictionary services. The DBMS selected by this evaluation process will then be used to prototype the data dictionary services.

3.17.2 ECS Benefit

The benefits of this prototype for ECS are:

- Validates the use of the selected DBMS product to implement the data dictionary services.
- Provides prototype code aimed specifically at the data dictionary services component in the Data Management Subsystem.

3.17.3 Community Benefit

The benefits of this prototype for ECS are:

- Provides the definition of the interfaces to the data dictionary service for data providers and system builders.

3.18 Data Migration

3.18.1 Description

The migration of data to and from the archive(s) is a complex problem. Analysis must be done to determine the possible implementations to "buffer" standing orders, store browse data, and provide working storage for processing such as data conversions, subsetting, and other processing. The initial phase of this prototype will be a trade study to evaluate COTS and research systems that provide intelligent staging techniques such as pre-emptive caching, incremental caching, etc. The prototyping phase will encompass the implementation of one or more of these COTS or research systems to evaluate the functionality, performance, and bottlenecks under a user load that includes data push, user pull, and data processing requests. This prototype will continue on past the Release A CDR, but some of the results will be fed into the Release A design.

3.18.2 ECS Benefit

The benefits of this prototype for ECS are:

- Defines staging strategies for the archive.
- Provides prototype code and COTS integration experience targeted directly at an SDPS component.

3.18.3 Community Benefit

The benefits of this prototype for ECS are:

- Will be involved in the evaluation of the staging strategies to provide feedback.

3.19 Other Prototyping / Study Activities

The previous sections have outlined the prototypes and studies that will be performed for SDPS for the Release A time frame. The intent of this paper was not to document all the possible prototypes that could be done or are being done related to SDPS. The intent was to provide a description of the framework of SDPS prototyping and a high-level description of the immediate prototyping needs in relationship to the ECS risks and SDPS design issues. There are other external prototyping and studies activities that will affect later designs of SDPS. Their full descriptions are not provided here in order to maintain clarity in this paper. Specifically, SDPS will be following the activities of the following prototypes, studies, or development efforts.

- DODS (Distributed Oceanographic Data System). Members of ECS have visited the University of Rhode Island and exchanged ideas about different architectural decisions.

DODS has shared their on-line documentation with ECS and ECS has shared the architecture white papers. This collaboration in terms of the sharing of results and directions will continue and develop as both projects progress.

- Independent Architecture Studies. Many of the Independent Architecture Studies focus on technology or design issues related to SDPS functions. The results of these activities are being monitored and fed back into the ECS project through the Hughes Research Laboratories (HRL) in Malibu, CA. HRL will continue to monitor their status as well as provide guidance to the organizations performing these studies. Specifically prototypes will be targetted at areas of concurrence between the ECS design and the studies. Further analysis will be undertaken for those areas where there are significant differences in design. HRL recently presented status to the ECS project and will continue to do so in order to provide results that can directly affect the SDPS architecture in the future.

4. Prototype Management

4.1 Authorization

SDPS prototypes conform to the ECS Prototyping and Studies Plan. The process for beginning work on a prototype is based on the prototype class as outlined in section 2.4 External vs. Internal Prototypes. In general the rules are:

- **Advanced Prototypes.** These prototypes usually involve funding outside of the ECS prototyping and development funding profiles. As such, they are proposed (either by the ECS contractors or outside organizations) to a Prototype Review Board. Selections are forwarded to the COTR for approval of additional funding.
- **Engineering and Technology Prototypes.** These prototypes are usually funded either from SDPS prototyping funds or SDPS development funds. The prototypes are proposed to the segment manager. If the prototype is to be funded from SDPS prototyping funds, the prototype must be approved by both the SDPS segment manager and the ECS Technical Manager (ETM), who is the ESDIS personnel responsible for the overall technical direction of prototypes. If the prototype is to be performed out of SDPS development funds, the SDPS segment manager has approval authority.

The full approval process is documented in the ECS Prototyping and Studies Plan. SDPS will follow the procedure outlined there. The prototype proposals must conform to the format documented in Appendix B of that document. The information that is required is: Title, Type, Category, Purpose, Objective, Approach, Evaluation Method, Risks Addressed, Effort (level of effort), Funding (funding source), and identification of lead engineers. The selection criteria for establishing whether a prototype should be performed are the following:

- Are the objectives consistent with and within the scope of the requirements?
- Is the proposed prototype or study feasible in terms of cost, schedule, and resources required?
- What is the potential contribution to ECS and the community?
- Does the prototype or study reduce risk or define a critical unknown design issue?
- Does the prototype or study affect mission critical areas?
- What is the priority of the proposed prototype with respect to other prototypes with the same funding source?
- What is the level of user participation required? Does the proposal include a plan to incorporate the necessary user input?

Several of the prototypes mentioned in this paper have been proposed to the SDPS segment manager and are in screening by the ETM. The prototypes are entered into a database that captures the goals and objectives of the prototype as well as the status as it progresses. The remaining prototypes in this paper that have not been entered in the database will be entered as soon as possible.

Figure 4 shows a high-level schedule of the prototypes. Many of the prototypes are complete or at an advanced stage by Release A PDR in order to provide enough information to feed the preliminary design. Others continue into Release B, but only their Release A schedules are shown. The Infrastructure Framework and EOSDIS Prototype are on-going activities with more long-term objectives.

[illegible]

4.3 Funding

- P = ECS prototyping funds (WBS 4.3)
- D = ECS development funds (WBS 4.4.x)
- U = University Outreach
- V = Vendor prototypes - These are unfunded prototypes provided by vendors. In other words, the vendors provide the prototypes on their own money.

The EOSDIS Prototype is being supported by SDPS, CSMS, and the EarthDS organizations. In Table 5, only the SDPS and funding provided to the EarthDS organization is shown. The CSMS effort is tracked and provided by CSMS.

If a column has two letters separated by a /, the funding source of this prototype has not been determined. For example, the LIM prototype has been discussed with a couple of DBMS vendors who are willing to develop prototypes on their own funds. This has not been investigated as a viable approach to prototyping, however. The LIM prototype is marked as P/D/V, since the funding source has not been defined.

Table 5. Funding Profiles for SDPS Prototypes

Prototype Name	Source(s)	SDPS Level of Effort (LM = labor months)
Infrastructure Framework	P	> 24LM
EOSDIS Prototype	P & U	13 LM
Advertising Service	P	5 LM
Data Type Services	P	18 LM
Earth Science Languages and Protocols	P/U	4 LM
Schema Maintenance Prototype	P	6 LM
Local Information Manager	P/D/V	6 LM
Distributed/Parallel Computing of Science Algorithms	P	22 LM
Network Attached Storage	P	48 LM
Multi-FSMS Integration	P	12 LM
SDPS Planning and Scheduling	P	20-24 LM
Data Compression	P	24 LM
Storage Systems Stress Tests & Benchmarks	P	12 LM
Physical Data Format Standards Study	P	60 LM
Data Processing	P	26 LM
Data Dictionaries / Vocabularies	P	6 LM
Data Migration	P	36 LM

4.4 Status and Reviews

The status of the prototypes will be tracked in the on-line database. The status will formally be reported quarterly in this database and the results will be presented at the Prototyping Results Reviews (PRR) as well as through the ECS Data Handling System (EDHS). Quarterly status may not be sufficient internally. There will be informal status reporting to the DTR on a regular basis in order to ensure the prototypes remain on course. This is an especially important task when parts or all of the prototype are performed outside of the ECS organization.

4.5 Results Incorporation

The SDPS development organizations will be responsible for determining the applicability of the results to the SDPS design. As stated earlier, each prototype will be evaluated by the development team that is most directly responsible for the function within SDPS. The evaluation criteria will be used to determine what pieces of the prototype design or code will be reused in the multi-track development cycle. Additional prototypes may be necessary based on the feedback of the development teams.

In most cases, the results of the prototypes will be documented in a white paper or technical note. These white papers or technical notes will be made available to the community through the EDHS. The white papers will also be used by the development organizations in evaluating the results of the prototypes.

Abbreviations and Acronyms

AFS	Andrew File System
AI&T	Algorithm Integration and Test
API	Application Programmer Interface
AVHRR	Advanced Very High Resolution Radiometer
CDR	Critical Design Review
CLI	Call Level Interface
CORBA	Common Object Request Broker Architecture
COTS	Commercial off-the Shelf
CSMS	Communications and System Management Segment
DBMS	Database Management System
DCE	Distributed Computing Environment
DIM	Distributed Information Manager
EarthDS	Earth Data System
ECS	EOSDIS Core System
EDF	ECS Development Facility
EOSDIS	Earth Observation System Data Information System
ETM	ECS Technical Manager
FOS	Flight Operations Segment
FSMS	File Storage Management System
FTP	file transfer protocol
GAC	Global Area Coverage
GCDIS	Global Change Data Information System
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HPCC	High Performance Computing and Communications
HRL	Hughes Research Laboratories
LIM	Local Information Manager
MODIS	Moderate-Resolution Imaging Spectroradiometer

NASA	National Aeronautics and Space Administration
NFS	Network File System
NIIT	National Information Infrastructure Testbed
ODP	Open Distributed Processing
OODBMS	Object-oriented Database Management System
OQL	Object Query Language
ORDBMS	Object-relational Database Management System
PDR	Preliminary Design Review
PGS	Product Generation System
RCP	remote copy
RDA	Remote Data Access
RDBMS	Relational Database Management System
RPC	remote procedure call
SCF	Science Computing Facility
SDPS	Science Data Processing Segment
SDR	System Design Review
SDS	System Design Specification
SI&P	System Integration and Planning
SQL3	Structured Query Language (version 3)